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Drought analysis based on SPI and RDI drought indices in the Burdur Basin

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Abstract

Drought is the most complex of the recurrent extreme weather events and is defined as a natural disaster with severe environmental, economic, and agricultural impacts resulting from a significant decrease in the average rainfall recorded in an area and the average rainfall recorded in the same place. Droughts have become more frequent and severe in many parts of the world, including Türkiye, due to global warming and climate change (increasing temperatures and changing precipitation patterns). Water resources and the agricultural sector are most severely affected by droughts. In this study, drought analyses of the Burdur Basin, located in the Aegean region, one of Türkiye's seven geographical regions, were carried out. For drought analysis, annual average total precipitation, annual maximum temperature, annual minimum temperature, and annual average temperature data of 17238 Burdur and 17892 Tefenni meteorological observation stations were used. Both meteorological and agricultural drought analyzes are included in the analysis of droughts. Standard Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) methods were used to determine meteorological and agricultural drought, respectively. SPI and RDI values were obtained for 1-, 3-, 6- and 12-month time periods, and the severity, size, and distribution of dry and humid periods were determined for both stations separately. When the results of both methods were examined, severe droughts were observed in the study area in 1973, 1978, 1981, and 2017.

1. Introduction

Natural disasters triggered by climate change, such as droughts, floods, sea level rise, and extreme weather events, are quite common in Türkiye. Especially water resources and the agriculture sector are seriously affected by droughts. Drought; It is defined as a natural disaster with serious environmental, economic, and agricultural effects that occurs as a result of the precipitation recorded in a region falling significantly below the average recorded in the same region [1, 2].

Drought, which is defined as one of the greatest natural disasters humanities has faced, has started to occur more frequently and severely over time with climate change [3]. Determining the drought severity for a particular region according to time and place is important in taking precautions in planning and managing water resources.

According to the variables used, drought can be grouped under four main headings: meteorological, hydrological, agricultural, and socio-economic [4-6]. Meteorological drought, one of these four groups, can be defined as the need for water due to the inadequacy of precipitation [7]. While hydrological drought, which is related to the effect of precipitation periods, is defined as the lack of soil and groundwater as a result of long-term precipitation deficiency, agricultural drought is expressed as the situation that occurs after meteorological drought and before hydrological drought and where there is not enough moisture in the roots of plants [8]. The presence of meteorological drought creates hydrological drought, and the formation of hydrological drought creates agricultural drought. At the end of all these, socio-economic famine drought is mentioned in the region where the drought occurs. Researchers have done many studies on drought. Inan et. al., [9] applied the annual drought analysis of 16 stations in the Black Sea Region with Standard Precipitation Index (SPI) and Percentage of Normal Index (PNI). It is stated in the study that the stations showed normal and above drought levels. Çıtakoğlu and Coşkun [10] investigated the short-term meteorological droughts with hybrid machine learning models using monthly precipitation data of Sakarya Meteorological Station. It is stated in the study that the hybrid models used together with the pre-processing techniques were found to be more successful than the stand-alone models. Coşkun and Çıtakoğlu [11] predicted the meteorological drought of Sakarya province for 1, 3, and 6-month time scales by using SPI. By using long short-term memory (LSTM), they concluded that drought time series do not need to be subjected to pre-processing techniques.

In this study the meteorological drought analysis of Burdur basin is investigated by using SPI and RDI method for 1-, 3-,6- and 12- months' time scales. The annual average total precipitation, annual maximum temperature, annual minimum temperature, and annual average temperature data of 17238 Burdur and 17892 Tefenni meteorological observation stations between1963-2021 were used. As a result of the study, the drought of the basin was evaluated temporally and the drought characteristics of the stations were determined. In this study, it is aimed to compare the SPI method, which analyzes drought using only precipitation data, and the RDI method, which uses minimum and maximum temperature parameters in addition to precipitation. Thus, it was aimed to determine the effect of temperature on drought in the region.

2. Method

2.1. Study Area

Burdur Basin, one of Türkiye's 25 basins, is a small, closed basin compared to other basins surrounded by Antalya and the Western Mediterranean Basins (Figure 1). Burdur Basin, which covers approximately 1% of Türkiye's surface area, has a precipitation area of 8,764 km^2. The basin is under the influence of a transitional climate between the continental and Mediterranean climates. The annual average precipitation is 446.0 mm/m^2, and the annual average temperature is 12°C [12].

2.2. Climate Data

Climate data is used in modeling to analyze climate change, trend analysis, and time-dependent atmospheric behaviors and to be prepared for disasters such as drought and flood [13,14]. At the same time, these data depend on analyzing extreme values, numerical model applications, and climate change projections to reduce disaster risk and climatic risk effects. For the Burdur Basin drought analysis, the data of the 17238 Burdur and 17892 Tefenni meteorological observation stations of the General Directorate of Meteorology has been used. The annual average total precipitation, annual maximum temperature, annual minimum temperature and annual average temperature observation data were used in the analysis. General information about the study area is given in Table 1.

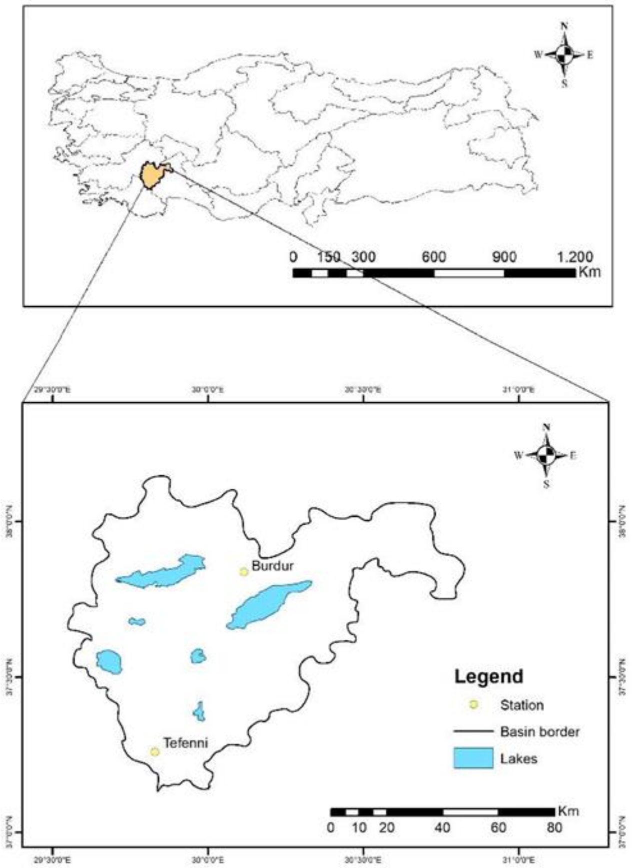

Figure 1. Burdur Basin location map.

Table 1. General information of the meteorological stations.

Station No	Station Name	Latitude	Longitude	Altitude (m)	Year	P_{avg} (mm)	T_{min} (°C)	T_{max} (°C)
17238	Burdur	37° 43' 00.0"	30° 18' 00.0"	957	1963-2021	420.1	-6.2	36.2
17892	Tefenni	37° 19' 00.0"	29° 46' 00.0"	1142	1963-2021	466.9	-9.1	35.1

2.3. Standard Precipitation Index (SPI)

The Standard Precipitation Index (SPI) method evaluates drought severity by calculating the lack of precipitation for different time series in rainy and dry periods [15]. The SPI method, which uses only precipitation data as input data, is one of the most widely used methods in determining meteorological drought [16]. While positive values calculated with this method determine the severity of rainy periods, negative values indicate the severity of drought [17]. While calculating the SPI, the gamma distribution is first applied to the long-term precipitation data. The calculated values are replaced in the formula given in Equation 1 to calculate the SPI.

$$SPI_{ij} = \frac{x_{ij} - x_{im}}{\sigma_i} \quad (1)$$

where x_{ij} is the precipitation in month j of the year (in mm), and x_{im} and σ_i are the mean and standard deviation, respectively. SPI values can be calculated for different time scales, such as short-term 1-, 3-, month, and long-term 6- and 12-month. The intensity values given in Table 2 can be used to classify drought [16, 18].

2.4. Reconnaissance Drought Index (RDI)

The reconnaissance drought index (RDI) is a drought analysis method that uses the potential evapotranspiration (PET) value and precipitation data. Minimum temperature and maximum temperature data are used to calculate PET values. In determining the RDI, it is first referred to as the initial value of the RDI. It is presented collectively using a monthly time step and calculated using Equation 2 for each month, season, or year of the hydrological year [17].

$$a_k^{(i)} = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} PET_{ij}} \quad (2)$$

where P_{ij} and PET_{ij} are i by hydrological year, respectively. j of the year are precipitation and PET values for the month, and N is the total number of years of available data. The second Normalized RDI (RDI_n) is calculated each year using Equation 3. Here, $\underline{a_k}$ parameter is the arithmetic mean of a_k values calculated for N years of data.

$$RDI_n^{(i)} = \frac{a_k^i}{\bar{a}_k} - 1 \quad (3)$$

In the standardized RDI (RDIst) calculation, the expression given in Equation 4 follows a procedure similar to that used for calculating the SPI.

$$RDI_{st(k)}^{(i)} = \frac{y_k^i - \bar{y}_k}{\hat{\sigma}_{yk}} \quad (4)$$

where y_k is calculated with $ln\, ln\, a_k^{(i)}$ while $\bar{y}_k$ and $\hat{\sigma}_{yk}$ denote the arithmetic mean and standard deviation of y_k respectively.

The intensity values given in Table 2 can be used to classify drought [16, 18].

Table 2. Severity classification for SPI and RDI.

Drought Classification	SPI/RDI
Extremely wet (EW)	2≤SPI/RDI
Severely wet (SW)	1.5≤SPI/RDI<2
Moderately wet (MOW)	1.0≤SPI/RDI<1.5
Mildly wet (MW)	1.0≤SPI/RDI<0
Mild drought (MD)	0≤SPI/RDI<-1.0
Moderate drought (MOD)	-1.0≤SPI/RDI<-1.5
Severe drought (SD)	-1.5≤SPI/RDI<-2
Extreme drought (ED)	SPI/RDI≤-2

3. Results

In this study, SPI and RDI index values were calculated, and drought analyzes were carried out using the annual average precipitation, maximum average, and minimum average temperature data observed between 1963-2021 of 17238 Burdur and 17892 Tefenni stations in the Burdur basin. By obtaining the temporal distributions of the SPI and RDI values obtained from 1-, 3-, 6- and 12-month time scales, it is possible to determine the conditions of EW, SW, MOW, MW and MD, MOD, SD, ED according to the drought severity classification given in Table 2. The number of occurrences and the percentages of dry and rainy periods observed in the study area were determined. Besides, according to the SPI and RDI values obtained for Burdur and Tefenni stations, the duration and time of the most severe drought period between 1963-2021 were determined, and the driest year between these years was determined.

3.1. Drought Analysis of Burdur Station

3.1.1. Drought analysis based on SPI

The temporal distribution of SPI values in the 1-, 3-, 6- and 12-month periods calculated using the monthly average precipitation data between 1963-2021 at Burdur station is given in Figure 2-5. According to Figure 2-5, as the period increases, the frequency of occurrence of dry periods also increases. As a result of the analysis, the highest droughts for the 1-, 3-, 6- and 12-month periods were seen in 1973, 1978, 1981, and 2017, respectively. The rainiest periods were experienced in 1991, 1997, and 2004, respectively.

In Figure 6, the percentages of occurrence of drought classes are given according to the SPI values obtained at the Burdur station. According to Figure 6, in the period examined at Burdur station, mild drought and mildly wet periods are experienced in general. As the time period increased, the percentage of mildly drought periods that occurred increased. In addition, as the time period increases, the percentages of occurrence of extremely drought periods decrease, while the percentages of occurrence of extremely wet periods increase.

The duration, intensity, and maximum occurrence values of the arid values obtained by SPI in the 1-, 3-, 6- and 12-month periods between 1963-2021 at Burdur station are given in Table 3. According to Table 3, it was clearly seen that the drought severity and duration increased as the period increased. However, with the increase of the period, it is seen that the highest drought value between 1963-2021 decreased in absolute terms. The maximum drought for the 1-, 3-, 6-, and 12-month periods occurred in 1973, 1978, 1981, and 2017, respectively.

3.1.2. Drought analysis based on RDI

The temporal distribution of SPI values in the 1-, 3-, 6- and 12-month periods calculated using the monthly average precipitation data between 1963-2021 at Burdur station is given in Figure 2-5. According to Figure 2-5, as the period increases, the frequency of occurrence of dry periods also increases. As a result of the analysis, the highest droughts for the 1-, 3-, 6- and 12-month periods were seen in 1973, 1978, 1981, and 2017, respectively. The rainiest periods were experienced in 1991, 1997, and 2004, respectively.

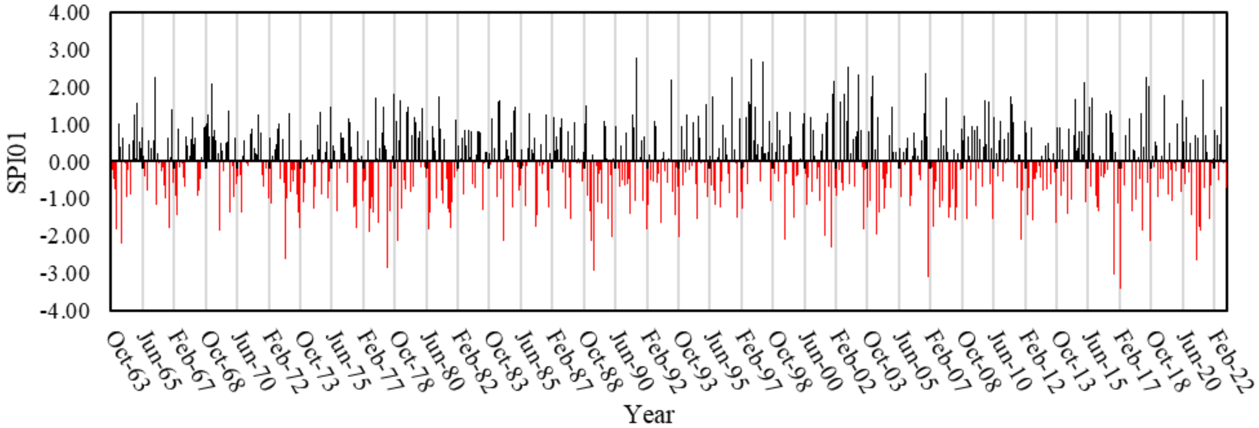

Figure 2. Temporal distribution of Burdur station SPI01 values.

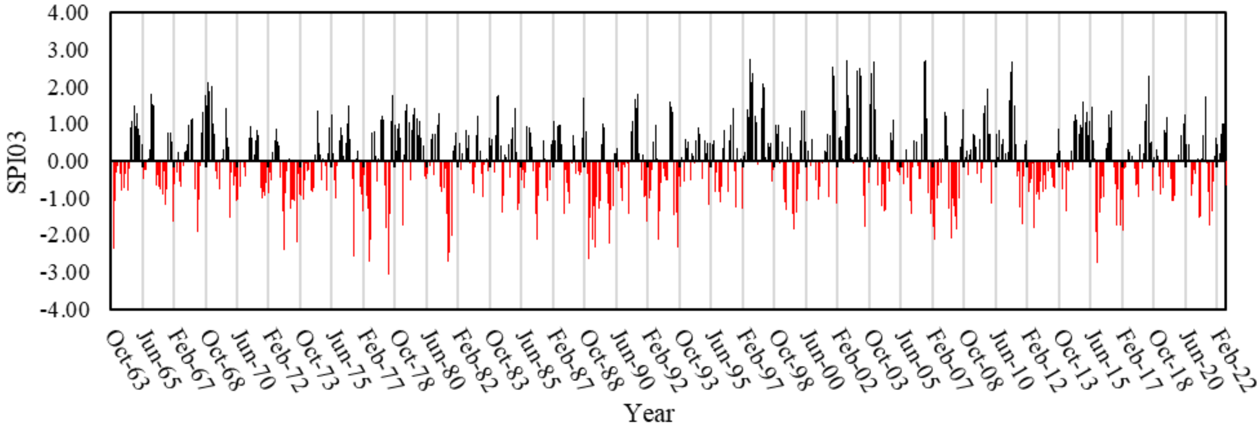

Figure 3. Temporal distribution of Burdur station SPI03 values.

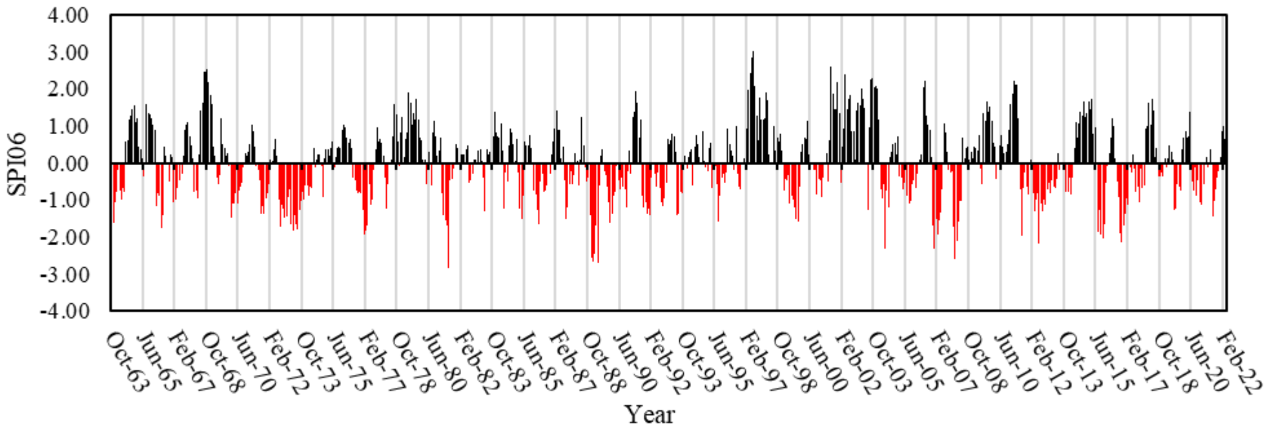

Figure 4. Temporal distribution of Burdur station SPI06 values.

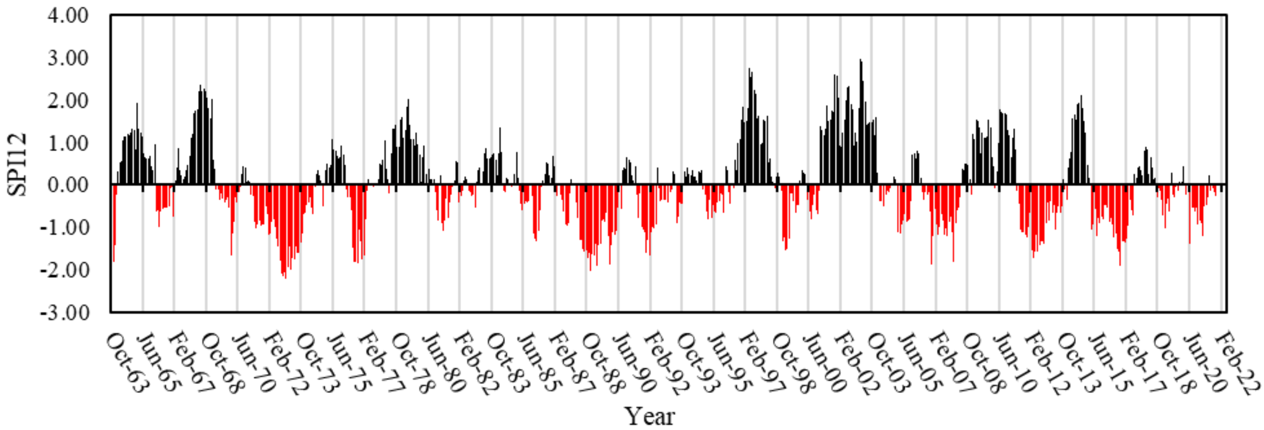

Figure 5. Temporal distribution of Burdur station SPI12 values.

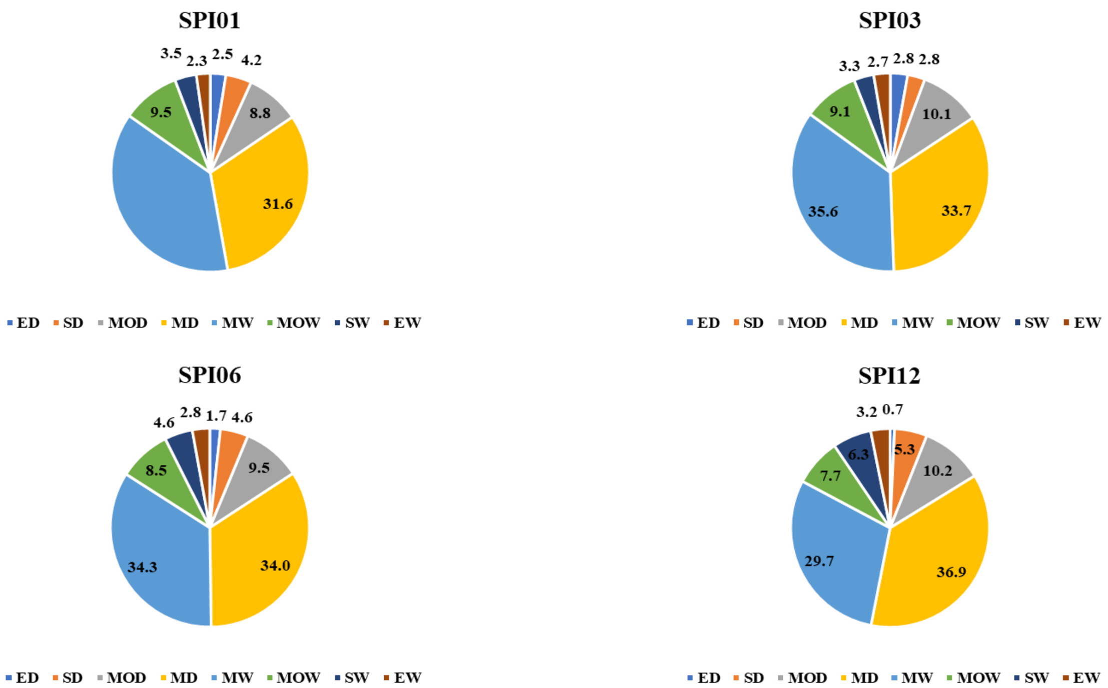

Figure 6. Occurrence percentages of drought classes (SPI) at Burdur station.

Table 3. Duration, severity and maximum occurrence values (SPI) of drought at Burdur station.

Period	Severity	Time (Month)	Start	Finish	Pick Value	Pick Time
SPI01	-6.52	6	Dec.06	May.07	-3.41	Feb.17
SPI03	-13.6	9	Jan.89	Sep.89	-3.07	Jul.78
SPI06	-25.5	22	Dec.72	Sep.74	-2.86	Nov.81
SPI12	-46.3	41	Jan.72	May.75	-2.23	Nov.73

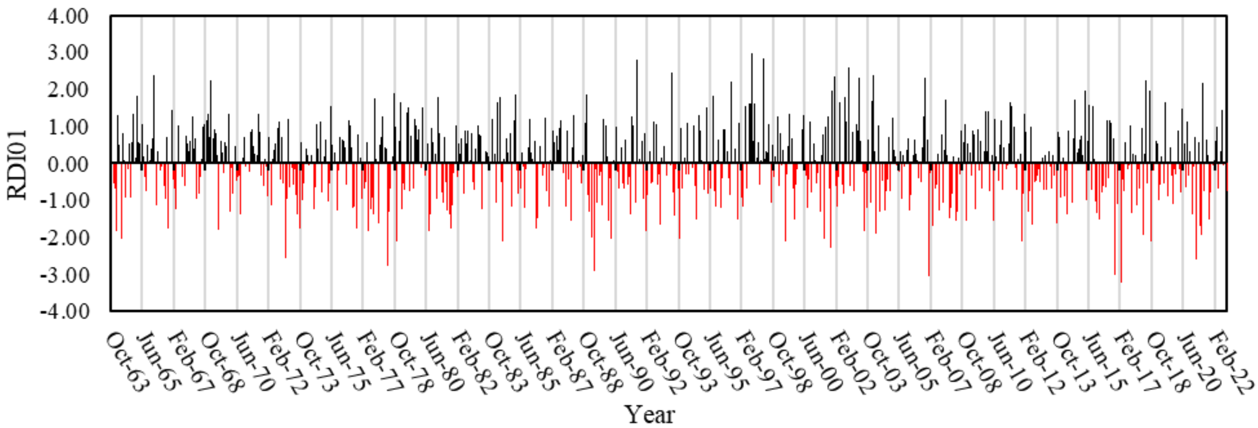

Figure 7. Temporal distribution of Burdur station RDI01 values.

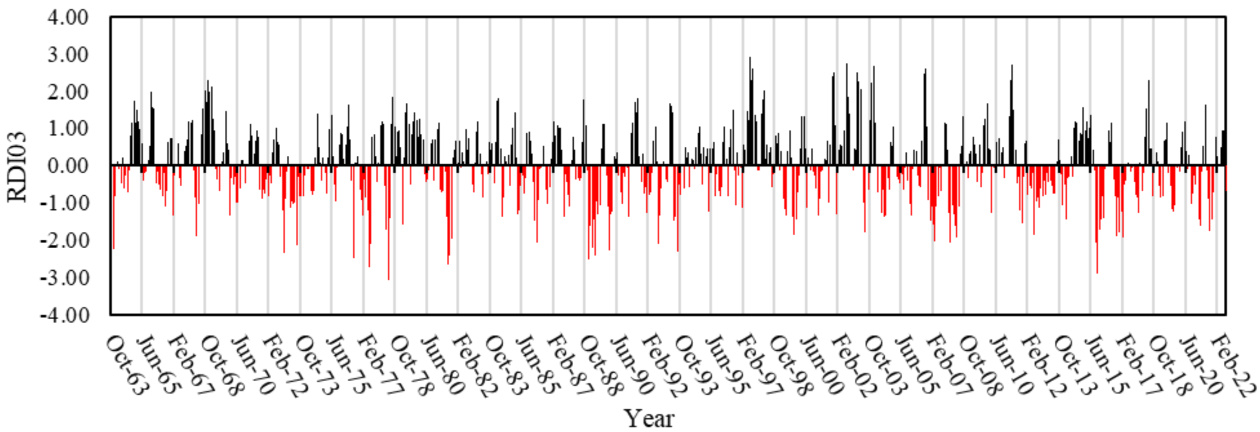

Figure 8. Temporal distribution of Burdur station RDI03 values.

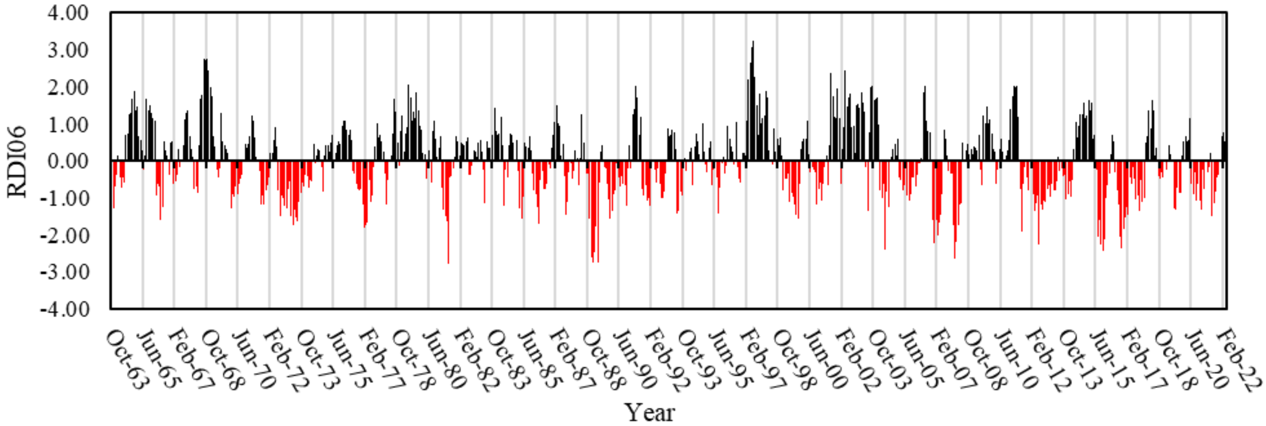

Figure 9. Temporal distribution of Burdur station RDI06 values.

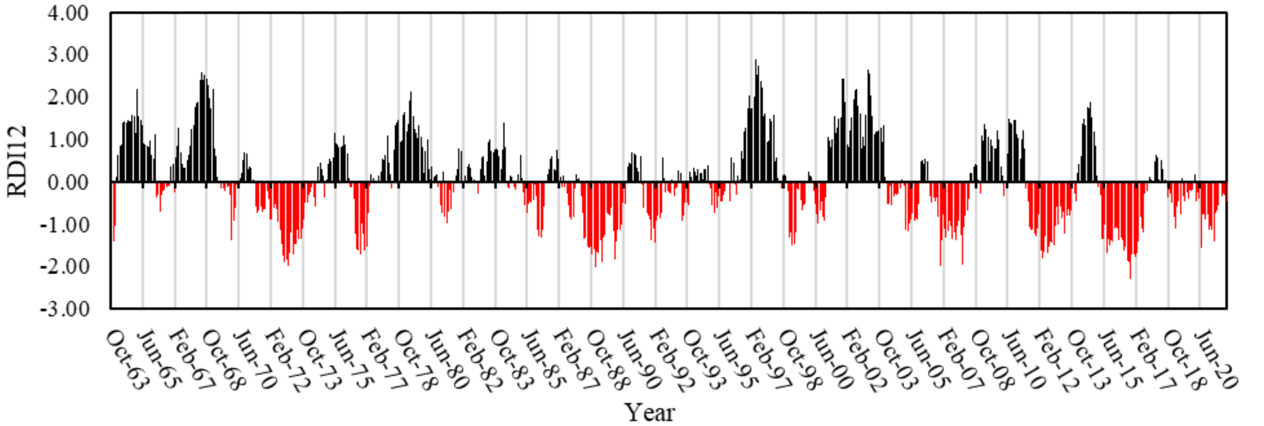

Figure 10. Temporal distribution of Burdur station RDI12 values.

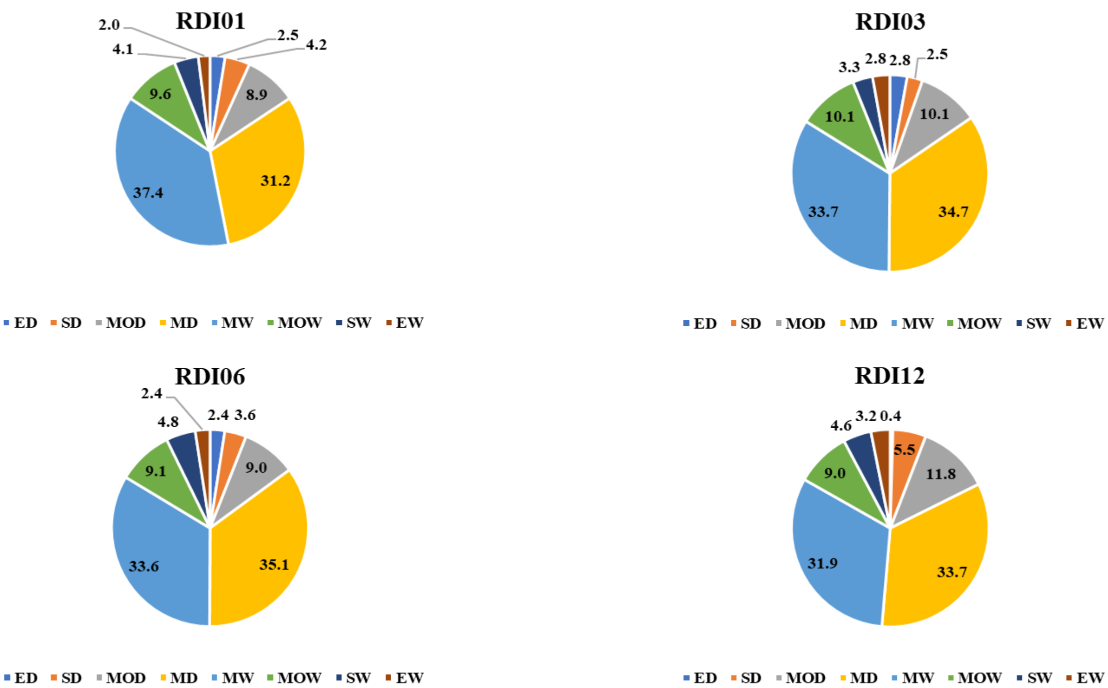

Figure 11. Occurrence of drought classes at Burdur station (RDI).

Table 4. Duration, severity and maximum occurrence values (RDI) of drought at Burdur station.

Period	Severity	Time (Month)	Start	Finish	Pick Value	Pick Time
RDI01	-10.01	10	Dec.88	Sep.89	-3.25	Feb.17
RDI03	-13.7	9	Jan.89	Sep.89	-3.07	Jul.78
RDI06	-21.7	22	Dec.72	Sep.74	-2.79	Nov.81
RDI12	-40.1	32	Jan.16	Jul.18	-2.30	Sep.17

The temporal distribution of RDI values in the 1-, 3-, 6- and 12-month periods calculated using the monthly average precipitation, maximum average, and minimum average temperature data between 1963-2021 at Burdur station is given in Figure 7-10. When the Figure 7-10 are examined, it is seen that while the drought intensity decreases as the period increases, the drought period increases. The highest drought SPI results for the 1-, 3-, and 6-month periods were seen in 1973, 1978, 1981, and 2017, similar to the results. For the 12 months, the driest year was determined as 2017. The rainiest periods were experienced in 1997 and 1998, respectively.

In Figure 11, the percentages of occurrence of drought classes are given according to the RDI values obtained at the Burdur station. As can be seen from the figures, mild drought and mildly wet drought classes are generally experienced in Burdur station, according to the drought occurrence percentages obtained with RDI, similar to the SPI percentages. As the period increased, an increase was observed in the percentage of mild drought periods, while the percentages of occurrence of extreme drought periods decreased.

The duration, intensity, and maximum occurrence values of the arid values obtained by RDI in the 1-, 3-, 6- and 12-month periods between 1963-2021 at Burdur station are given in Table 4. According to the Table 4, it was clearly seen that the severity and duration of drought increased as the period increased. However, it is seen that the highest drought value of the period decreased in absolute terms. The maximum drought for the 1-, 3-, and 6-month periods is the same as the SPI and occurred in July 1978, November 1981, September 2017, and February 2017, respectively. For the 12 months, the maximum drought was observed in September 2017. When the values calculated by SPI and RDI in 1-, 3-, 6- and 12-month time periods were examined in general, it was observed that 1973, 1978, 1981, and 2017 were generally dry.

3.2. Drought Analysis of Tefenni Station

3.2.1. Drought analysis based on SPI

When the temporal distributions of the 1-, 3-, 6- and 12-month periods of the SPI values calculated using the monthly average precipitation data between 1963-2021 at Tefenni station are examined (Figure 12-15), it is seen that the period of the dry periods increases as the period increases. In addition, it is understood from the Figure 12-15 that the value of the maximum dry and rainy period decreases with the increase of the period. For the 1-, 3-, 6-, and 12-month periods, the highest droughts were observed in 1989, 2017, and 2021, respectively. The wettest periods were observed in December 2001 in the 1-, 3-, and 6-month periods and in January 1966 in the 12-month period.

According to the results of SPI analysis made with Tefenni station data, the percentages of occurrence of drought classes are given in Figure 16. Accordingly, when all periods are considered at Tefenni station, it is seen that mild drought and mildly wet drought classes are predominantly experienced according to the percentages of drought formation obtained with SPI. As the period increased, there was a decrease in the percentage of mild drought periods, while the percentages of extreme drought periods in general decreased. However, as the period increased, there was an increase in the moderate drought and moderately wet periods.

The duration, intensity, and maximum occurrence values of the arid values obtained by SPI in the 1-, 3-, 6- and 12-month periods between 1963-2021 at Tefenni station are given in Table 5. According to the Table 5, it was clearly seen that the drought severity and period increased as the period increased. However, it is observed that the highest drought value occurring in 1-, 3-, 6- and 12-month periods decreased in absolute terms. For the 1-, 3-, 6-, and 12-month periods, the maximum drought occurred in June 1989, January 1990, February 2017, and September 2021, respectively. In general, it was observed that a dry period started at the end of 1988.

Table 5. Duration, severity and maximum occurrence values (SPI) of drought at Tefenni station.

Period	Severity	Time (Month)	Start	Finish	Pick Value	Pick Time
SPI01	-11.7	10	Dec.88	Sep.89	-3.32	Feb.17
SPI03	-17.8	10	Jan.89	Oct.89	3.88	Sep.22
SPI06	-44.5	35	Jan.89	Nov.91	-3.36	Jul.89
SPI12	-79.2	59	Mar.89	Jan.94	-2.80	Jan.90

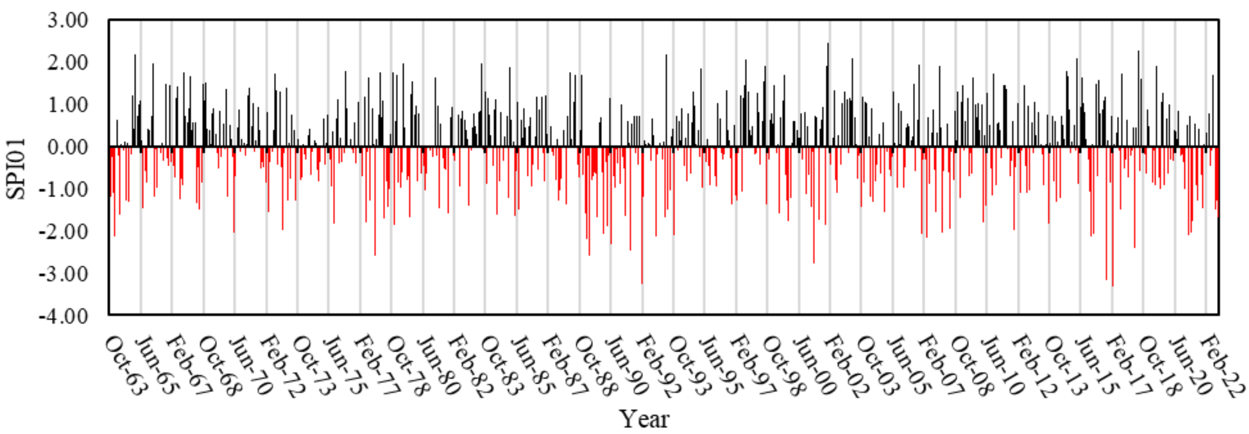

Figure 12. Temporal distribution of Tefenni station SPI01 values.

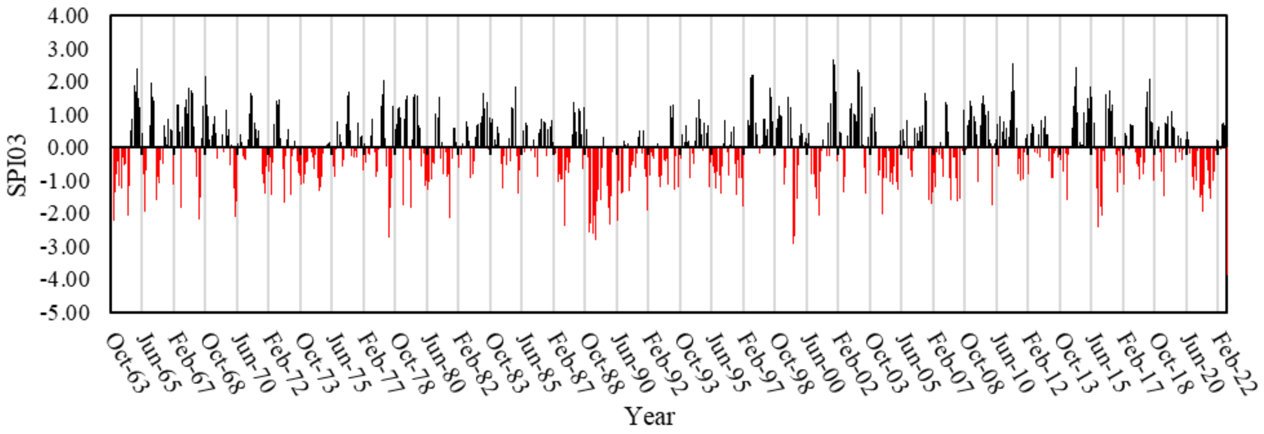

Figure 13. Temporal distribution of Tefenni station SPI03 values.

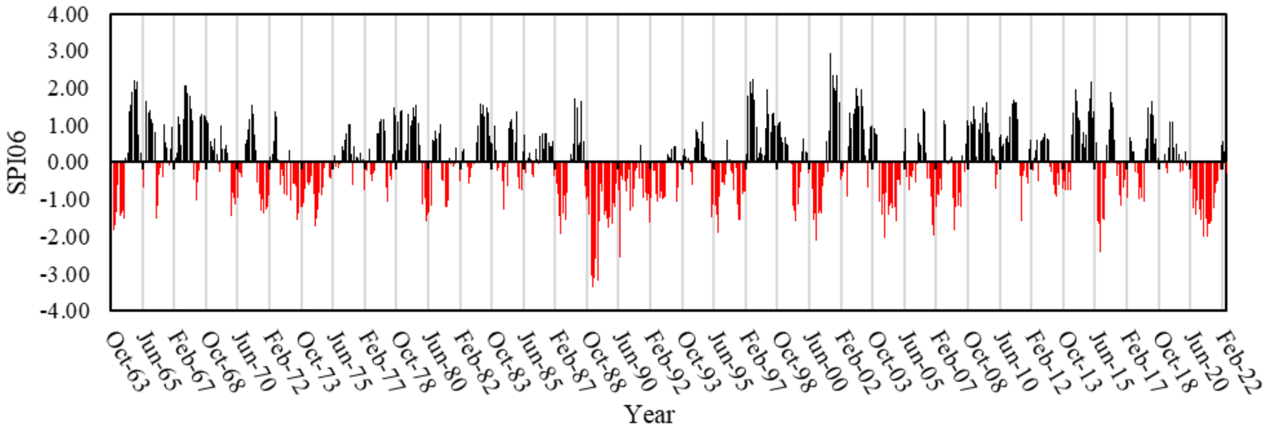

Figure 14. Temporal distribution of Tefenni station SPI06 values.

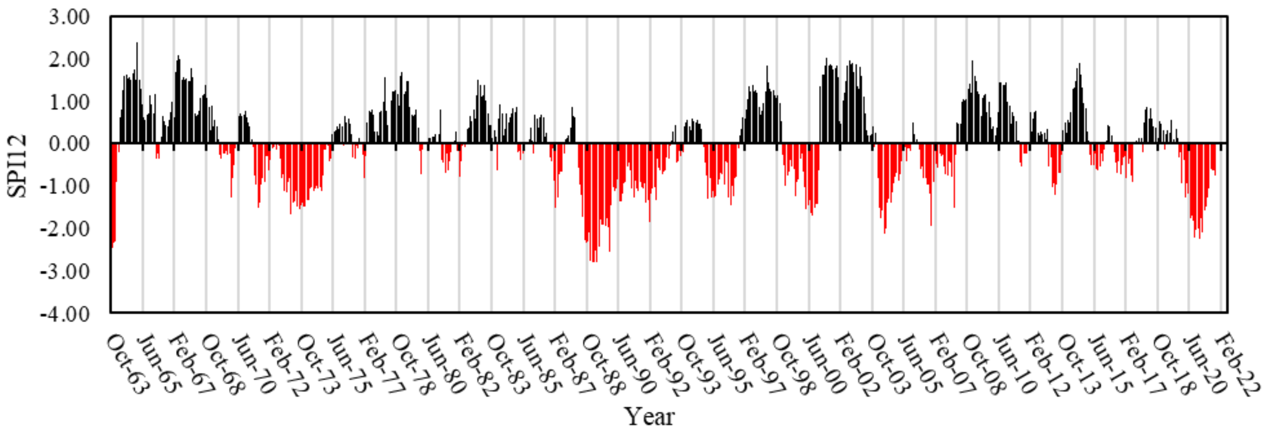

Figure 15. Temporal distribution of Tefenni station SPI12 values.

3.2.2. Drought analysis based on RDI

The temporal distribution of the RDI values calculated using the monthly average precipitation data between 1963-2021 at Tefenni station for 1-, 3-, 6- and 12-month periods is given in Figure 17-20. According to Figure 17-20, as in all periods and all drought indices, it is seen that the period of dry periods increases as the period increases. In addition, it was observed that the value of the maximum dry and rainy period decreased with the increase of the period. The highest drought for the 1-, 3-, 6-, and 12-month periods was seen in 1989, 2017, and 2021, respectively, similar to the SPI index. According to the RDI and SPI indexes, the date of the maximum drought at Tefenni station was the same. The wettest periods were observed in December 2001 in the 1- and 6-month periods and in January 1966 and June 2011 in the 3- and 12-month periods, respectively.

The duration, intensity, and maximum occurrence values of the arid values obtained by RDI in the 1-, 3-, 6- and 12-month periods between 1963-2021 at Tefenni station are given in Table 6. According to Table 6, drought severity and duration increase as the period increases. However, it is observed that the highest drought value occurring in 1-, 3-, 6- and 12-month periods decreased in absolute terms. For the 1-, 3-, 6-, and 12-month periods, the maximum drought occurred in June 1989, January 1990, February 2017, and September 2021, respectively. In general, a dry period started at the end of 1988.

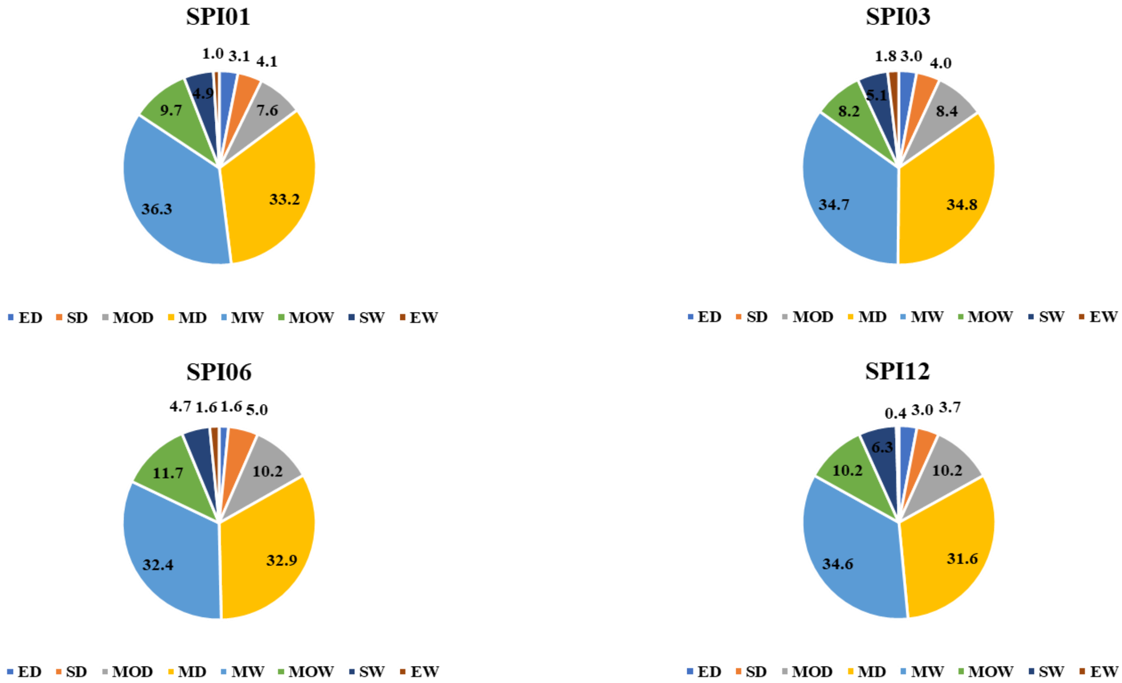

Figure 16. Occurrence percentages of drought classes (SPI) at Tefenni station.

Table 6. Duration, severity and maximum occurrence values (RDI) of drought at Tefenni station.

Period	Severity	Time (Month)	Start	Finish	Pick Value	Pick Time
RDI01	-11.56	10	Dec.88	Sep.89	-3.15	Feb.17
RDI03	-17.35	10	Jan.89	Oct.89	-3.87	Sep.22
RDI06	-43.15	35	Jan.89	Nov.91	-3.34	Jul.89
RDI12	-73.51	59	Mar.89	Jan.94	-2.79	Jan.90

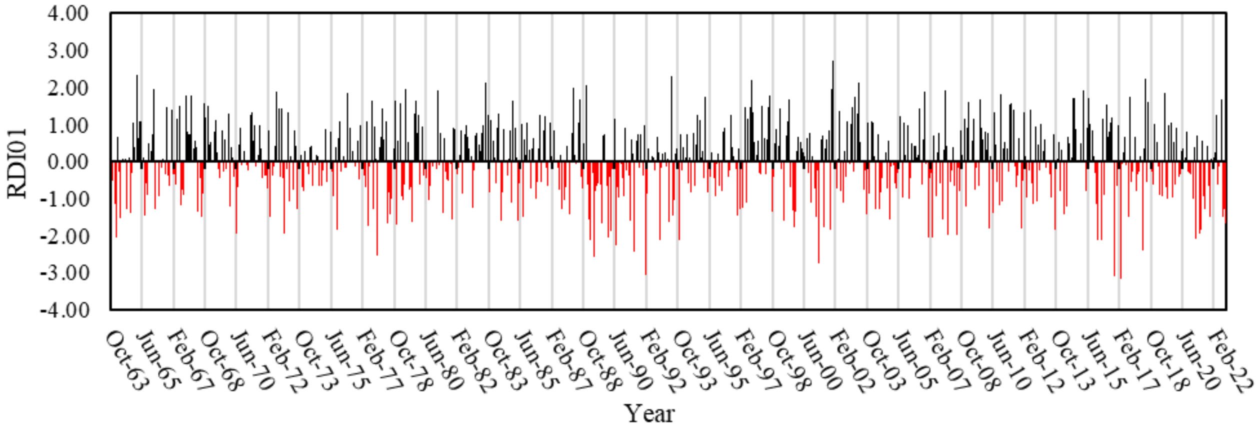

Figure 17. Temporal distribution of Tefenni station RDI01 values.

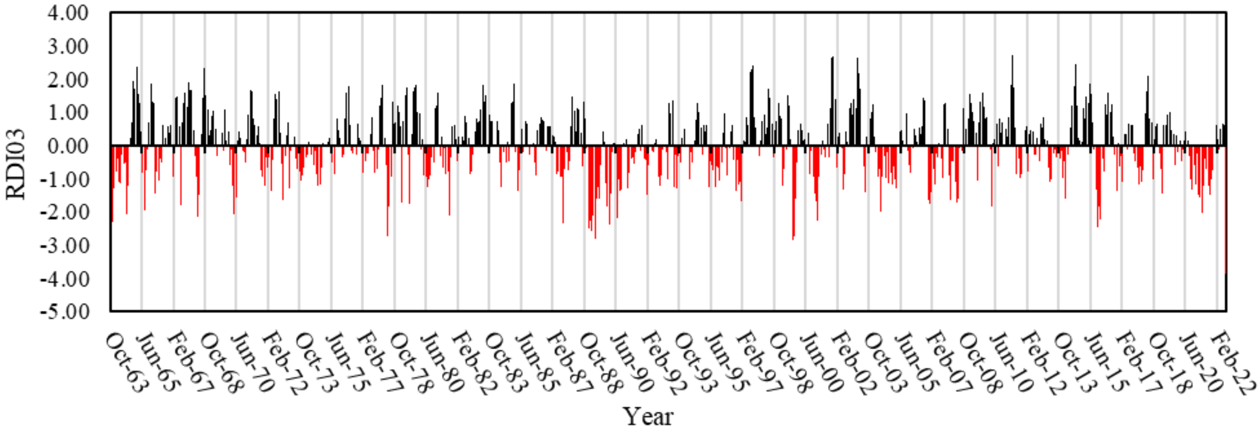

Figure 18. Temporal distribution of Tefenni station RDI03 values.

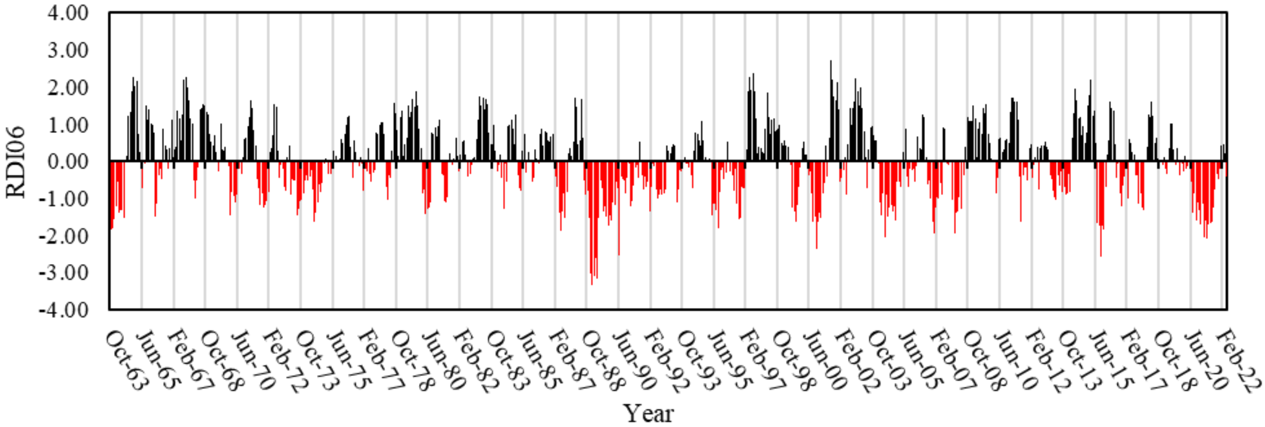

Figure 19. Temporal distribution of Tefenni station RDI06 values.

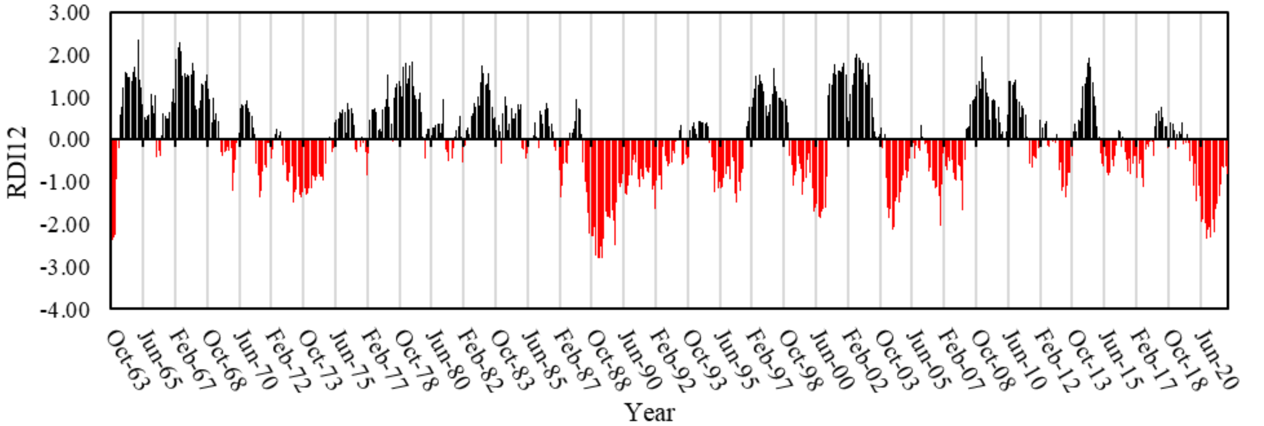

Figure 20. Temporal distribution of Tefenni station RDI12 values.

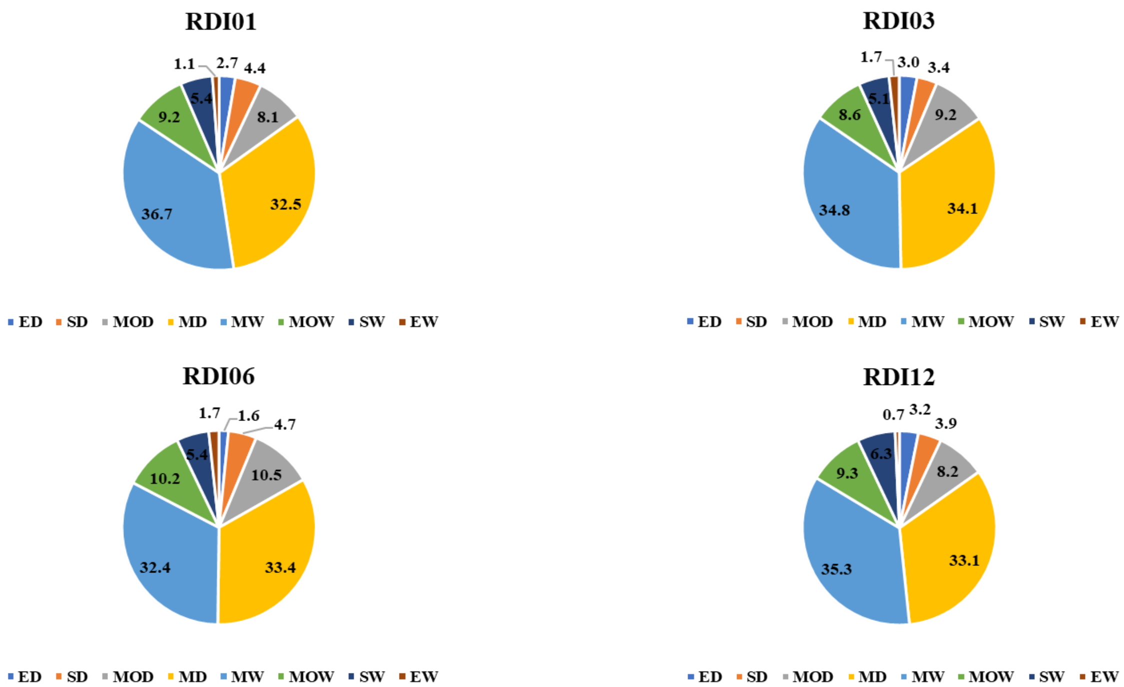

Figure 21. Occurrence percentages of drought classes (RDI) at Tefenni station.

4. Discussion

This study conducted meteorological and agricultural drought analysis in the Burdur Basin in the Aegean Region. For this purpose, meteorological and agricultural droughts for 1963-2021 were analyzed using the average precipitation, average minimum and maximum temperatures observed in Burdur No. 17238 and Tefenni

No. 17892 in the Burdur Basin. By applying Standard Precipitation Index (SPI) and Exploratory Drought Index (RDI) methods to the data sets, respectively, the severity, size, and distribution of dry and humid periods were determined by the SPI and RDI values calculated for 1-, 3-, 6- and 12-month periods.

When the SPI results are examined, the number of extreme drought months observed between 1963-2021 was 6, 9, 22, and 41 for the Burdur station in 1-, 3-, 6- and 12-month periods, respectively; 10, 10, 35 and 59 respectively for Tefenni station. In the examined period, maximum droughts for 1-, 3-, 6- and 12-month periods were experienced in Burdur station in July 1978, November 1973, November 1981, and February 2017, and at Tefenni station in June 1989, January 1990, February 2017 and September 2021.

When the RDI results are examined, the number of extreme drought months observed between 1963-2021 was 10, 9, 22, and 32 for the Burdur station in 1-, 3-, 6- and 12-month periods, respectively; 10, 10, 35 and 59 respectively for Tefenni station. In the examined period, maximum droughts for 1-, 3-, 6- and 12-month periods were experienced at Burdur station in July 1978, November 1981, September 2017, and February 2017, and at Tefenni station in June 1989, January 1990, February 2017 and September 2021.

When the values calculated by SPI and RDI were examined in general, it was observed that the years 1973, 1978, 1981, and 2017 were generally dry in the study area.

5. Conclusion

As a result of the analysis, the severity and duration of droughts in the Burdur basin have increased in recent years, and meteorological drought; agricultural drought has been observed. In order to combat the devastating effects of the drought disaster in the Burdur Basin, which is an important area for our country in terms of water resources, it will be beneficial to regularly monitor the variability in climatological data and develop local policies that will ensure the effective management of water resources. In addition, determining hydrological droughts and precipitation trends for the same region will be an important resource for water management studies.

Author contributions

Nazire Göksu Soydan Oksal: Conceptualization, Methodology, Original draft preparation and Editing.
Neslihan Beden: Data curation, Methodology, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Kundzewicz, Z. W., & Robson, A. (2000). Detecting trend and other changes in hydrological data. World Climate Programme Data and Monitoring, WCDMP – 45
2. Beşel, C., & Kayikci, E. T. (2020). Investigation of Black Sea mean sea level variability by singular spectrum analysis. International Journal of Engineering and Geosciences, 5(1), 33-41. https://doi.org/10.26833/ijeg.580510
3. Ojha, S. S., Singh, V., & Roshni, T. (2021). Comparison of meteorological drought using SPI and SPEI. Civil Engineering Journal, 7(12), 2130-2149. http://dx.doi.org/10.28991/cej-2021-03091783
4. Zarch, M. A. A., Sivakumar, B., & Sharma, A. (2015). Droughts in a warming climate: A global assessment of Standardized precipitation index (SPI) and Reconnaissance drought index (RDI). Journal of Hydrology, 526, 183-195. https://doi.org/10.1016/j.jhydrol.2014.09.071
5. Surendran, U., Kumar, V., Ramasubramoniam, S., & Raja, P. (2017). Development of drought indices for semi-arid region using drought indices calculator (DrinC)–a case study from Madurai District, a semi-arid region in India. Water Resources Management, 31, 3593-3605. https://doi.org/10.1007/s11269-017-1687-5
6. An, S., Park, G., Jung, H., & Jang, D. (2022). Assessment of future drought index using SSP scenario in Rep. of Korea. Sustainability, 14(7), 4252. https://doi.org/10.3390/su14074252
7. Mishra, A. K., & Singh, V. P. (2010). A review of drought concepts. Journal of Hydrology, 391(1-2), 202-216. https://doi.org/10.1016/j.jhydrol.2010.07.012
8. Wilhite, D. A., & Glantz, M. H. (1985). Understanding: The Drought Phenomenon: The Role of Definitions. Water International, 10, 111-120.
9. İnan, B., Demir, V., & Sevimli, M. F. (2021). Drought analysis of Black Sea Region by standardized precipitation index (SPI) and percent of normal index (PNI). Advanced Engineering Days (AED), 1, 8-10.
10. Citakoglu, H., & Coşkun, Ö. (2022). Comparison of hybrid machine learning methods for the prediction of short-term meteorological droughts of Sakarya Meteorological Station in Turkey. Environmental Science and Pollution Research, 29(50), 75487-75511. https://doi.org/10.1007/s11356-022-21083-3
11. Coşkun, Ö., & Citakoglu, H. (2023). Prediction of the standardized precipitation index based on the long short-term memory and empirical mode decomposition-extreme learning machine models: The Case of Sakarya, Türkiye. Physics and Chemistry of the Earth, Parts A/B/C, 131, 103418. https://doi.org/10.1016/j.pce.2023.103418
12. SYGM, (2019). Burdur Havzası Taşkın Yönetim Planı. Ankara: Türkiye Cumhuriyeti Tarım ve Orman Bakanlığı.
13. Ünel, F. B., Kuşak, L., Yakar, M., & Doğan, H. (2023). Coğrafi bilgi sistemleri ve analitik hiyerarşi prosesi

kullanarak Mersin ilinde otomatik meteoroloji gözlem istasyonu yer seçimi. Geomatik, 8(2), 107-123. https://doi.org/10.29128/geomatik.1136951
14. Demir, V., & Keskin, A. Ü. (2022). Yeterince akım ölçümü olmayan nehirlerde taşkın debisinin hesaplanması ve taşkın modellemesi (Samsun, Mert Irmağı örneği). Geomatik, 7(2), 149-162. https://doi.org/10.29128/geomatik.918502
15. Mohamed, M. J., Cemek, B., Küçüktopcu, E., Omar, A. A., & Hassan, S. M. (2022). Drought Analysis in Somalia Using GIS-Based on Reconnaissance Drought Index (RDI) and Standardized Precipitation Index (SPI). African Journal of Climate Change and Resource Sustainability, 1(1), 62-75. https://doi.org/10.37284/ajccrs.1.1.981
16. Beden, N., Demir, V., & Keskin, A. Ü. (2020). Samsun İlinde SPI ve PNI Kuraklık İndekslerinin Eğilim Analizi. Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi, 22(64), 107-116. https://doi.org/10.21205/deufmd.2020226411
17. Gümüş, V., Başak, A., & Oruç N. (2016). Standartlaştırılmış yağış indeksi (SYİ) yöntemi ile Şanlıurfa istasyonunun kuraklık analizi. Harran Üniversitesi Mühendislik Dergisi, 1(1), 36-44.
18. Tsakiris, G., Pangalou, D., & Vangelis, H. (2007). Regional drought assessment based on the Reconnaissance Drought Index (RDI). Water Resources Management, 21, 821-833. https://doi.org/10.1007/s11269-006-9105-4